Collinear Resonance Ionization Spectroscopy physics and progress at ISOLDE

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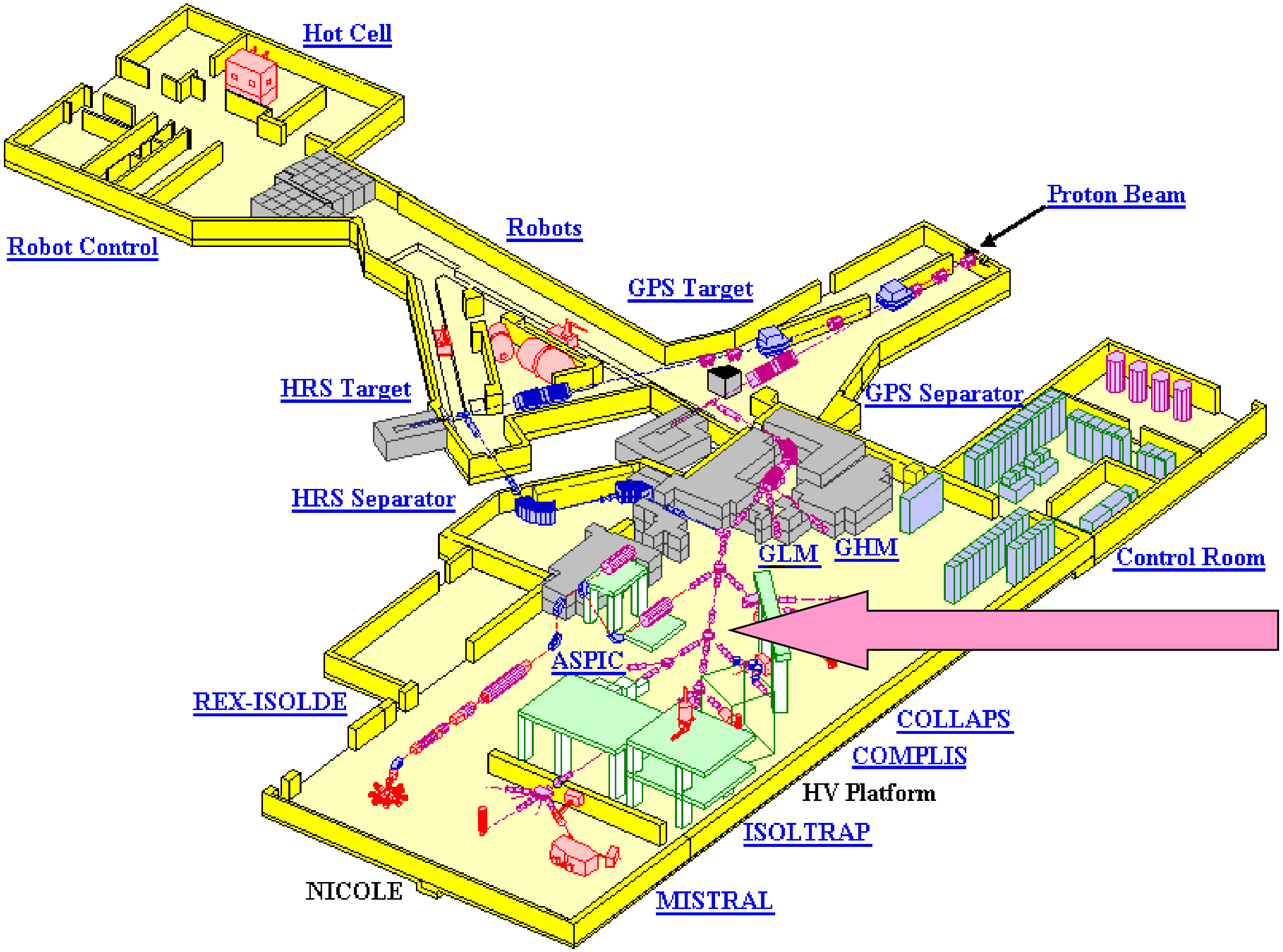
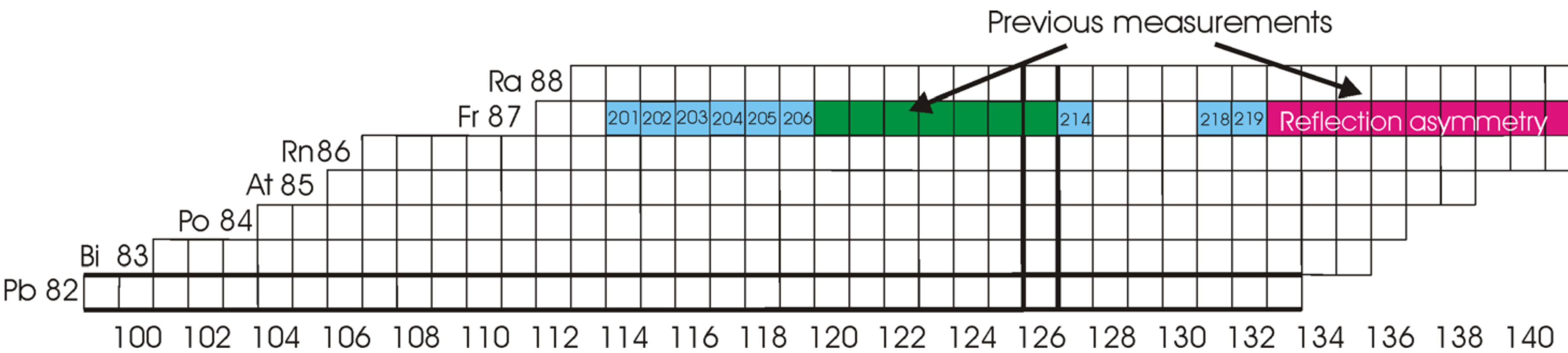
CRIS at ISOLDE



Outline

- Physics motivation
- CRIS – basic principle
- The experimental setup – beam optics
- Progress update
- The detection system

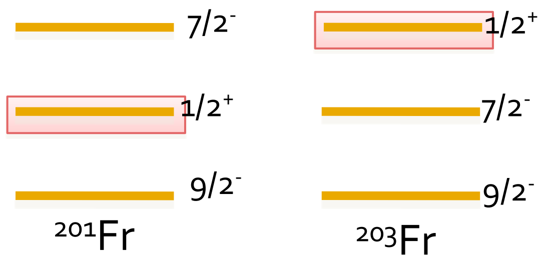
Physics motivation



- The ground state properties of Francium isotopes
- Surrounding isotopes: Radium (Ra) and Radon (Rn)
- Quadrupole moments and spin assignments in neutron deficient Po, Bi and Pb isotopes

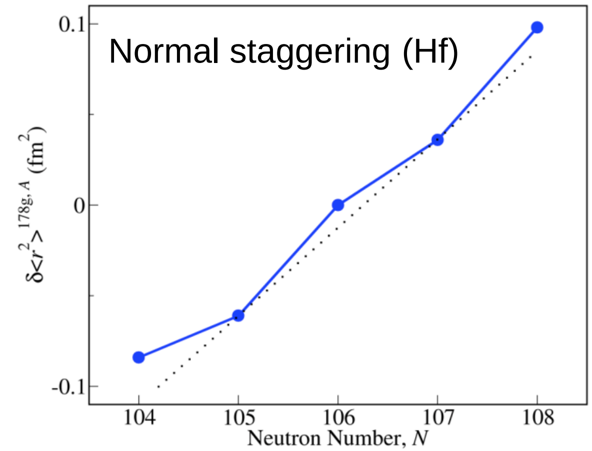
Spectroscopy of francium (Z=87)

Reordering of quantum states



Lowering of I=1/2$^+$ intruder state with decreasing *N*.

Suggestion that ^{199}Fr has I=1/2$^+$ ground state spin with an associated large oblate deformation.



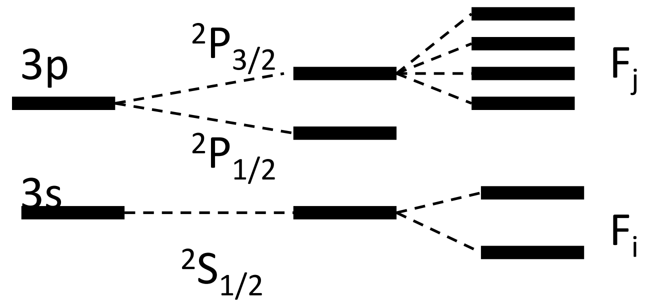
Region known to be characterised by reversal in odd-even staggering, which is attributed to presence of octupole-quadrupole deformation.

$$Q_s \rightarrow \langle \beta_2 \rangle$$

$$\langle r^2 \rangle \rightarrow \langle \beta_2^2 \rangle + \langle \beta_3^2 \rangle + \ldots$$

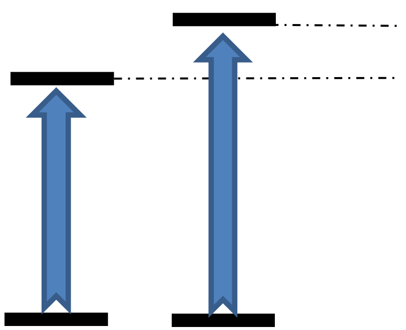
Nuclear moment and radii measurements with laser spectroscopy

Hyperfine Structure



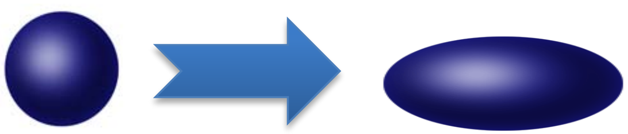
Spin, magnetic and electric moments , all nuclear observables are extracted without model dependence.

Isotope Shift

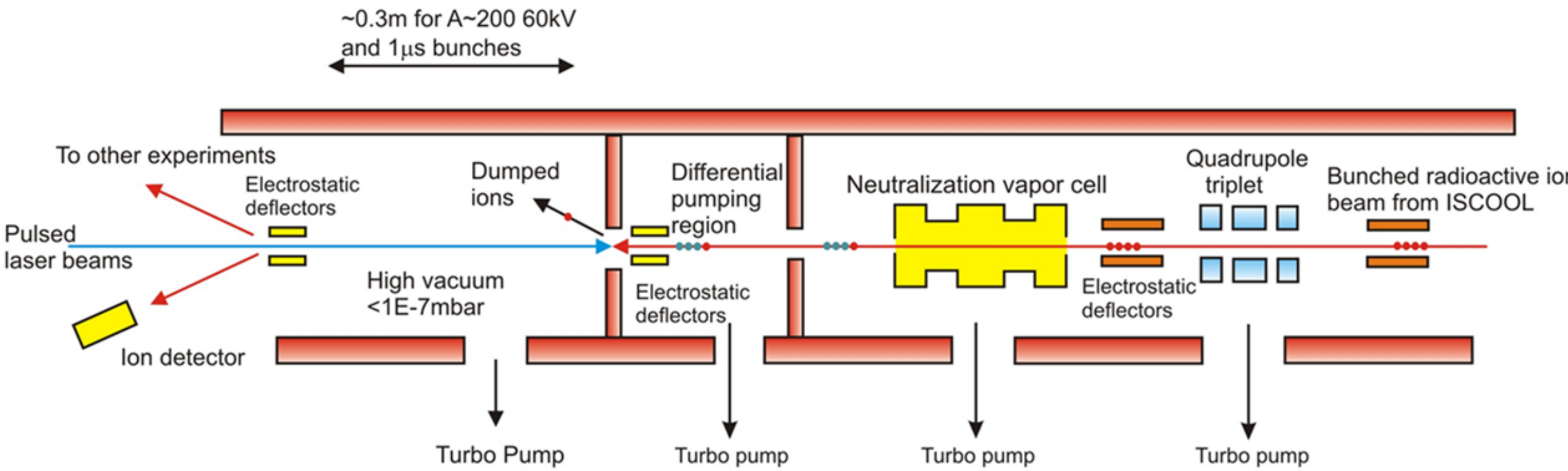


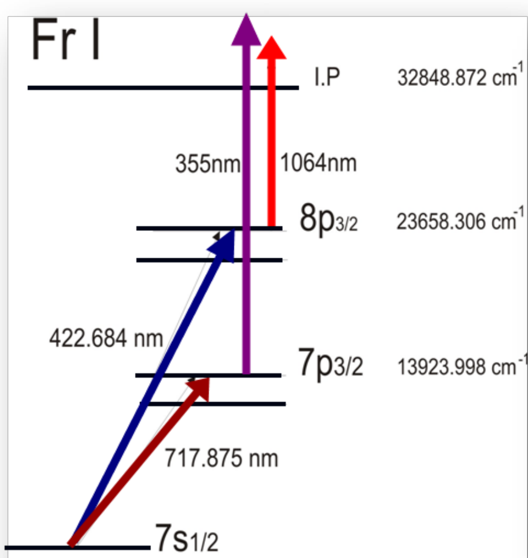
$$\Delta\nu_{IS} = \Delta\nu_{MS} + \Delta\nu_{FS}$$

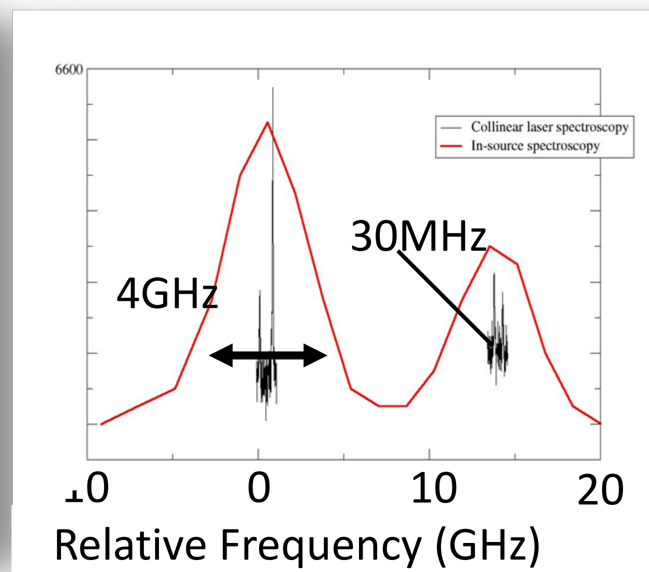
Changes in nuclear charge radii and sensitive to changes in dynamic nature and deformation as well as volume.



The basic principle of CRIS technique







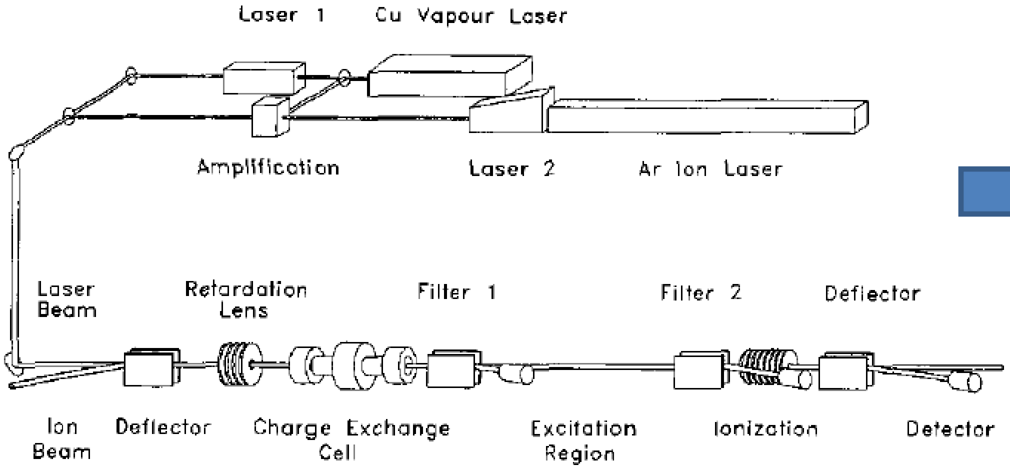
Combining high resolution nature of collinear beams method with high sensitivity of in-source spectroscopy.

Yu. A. Kudriavtsev and V. S. Letokhov, *Appl. Phys.* **B29** 219 (1982)

Previous CRIS of Yb at ISOLDE

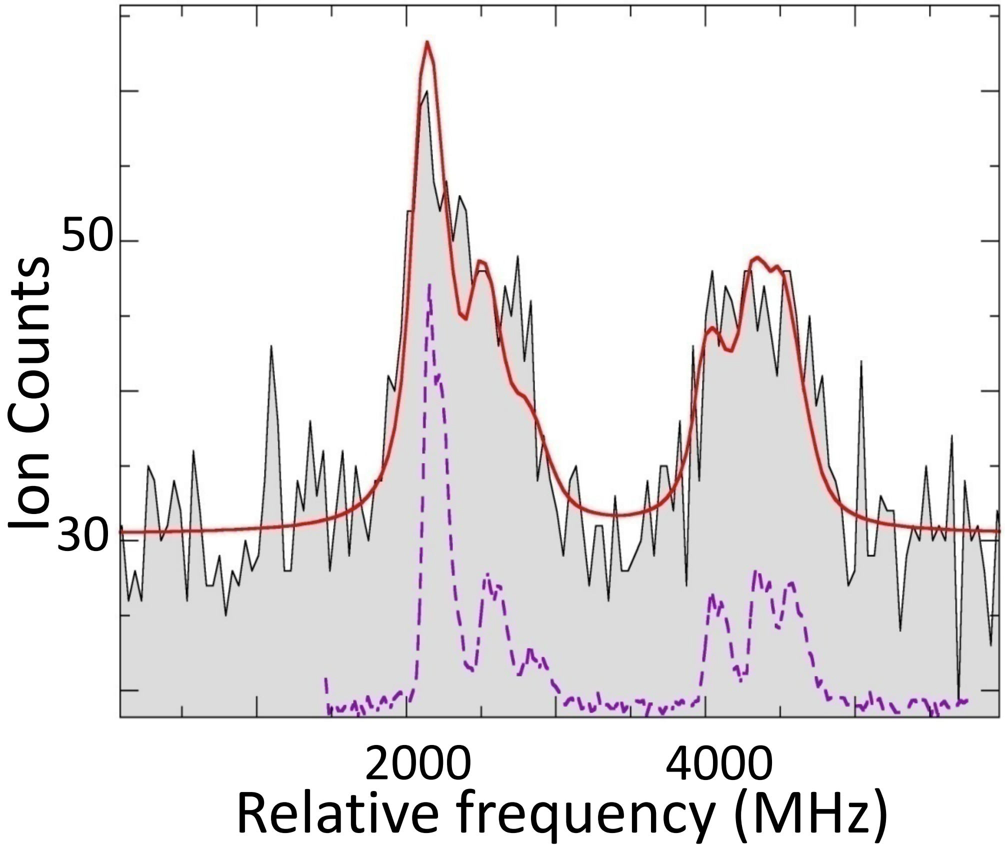
Ch. Schulz *et al.*, J. Phys. B, **24** (1991) 4831

- Charge exchange efficiency into meta stable states
- Below saturation on second step
- Duty cycle losses due to lasers



Total efficiency 1:100 000

Off-line CRIS test at the IGISOL



200 ions per bunch

6 scans

1:30 efficiency

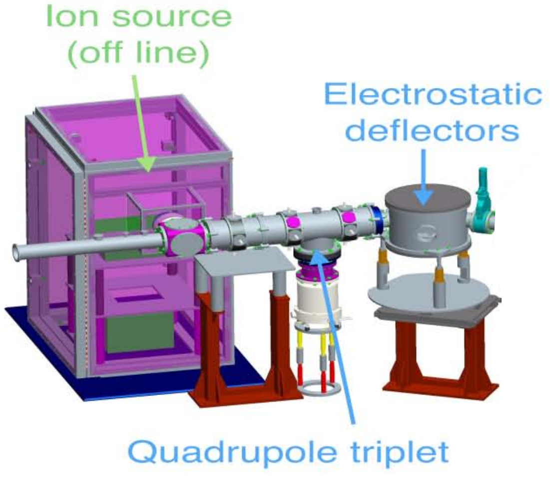
Factor of 1000 increase in detection efficiency.

Background due to non-resonant collisional ionization in poor vacuum (10^{-5} mbar)

~5 non-resonant ions per bunch

CRIS Beam optics

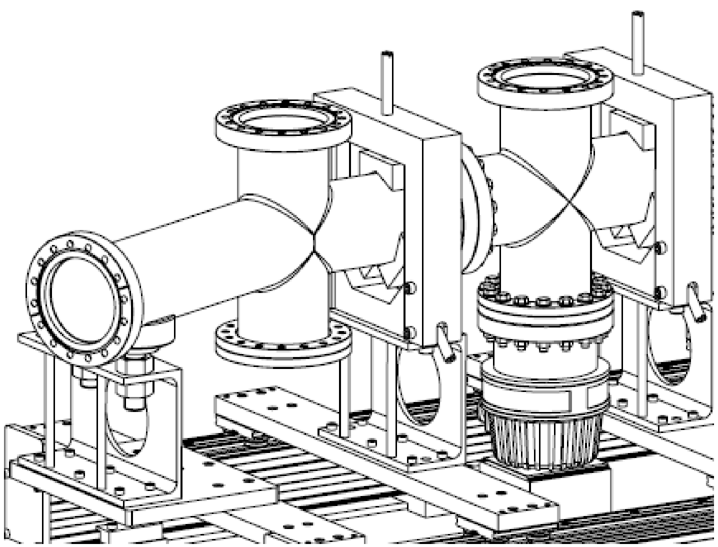
- Bunched, accelerated ions focused and steered through 34 bend
- Ions accelerated to scanned velocity and neutralized
  - Remaining ions deflected
- CW laser excites hyperfine structure. High power pulsed lasers used to ionize the excited atoms
- Resulting ions steered and focused to detector

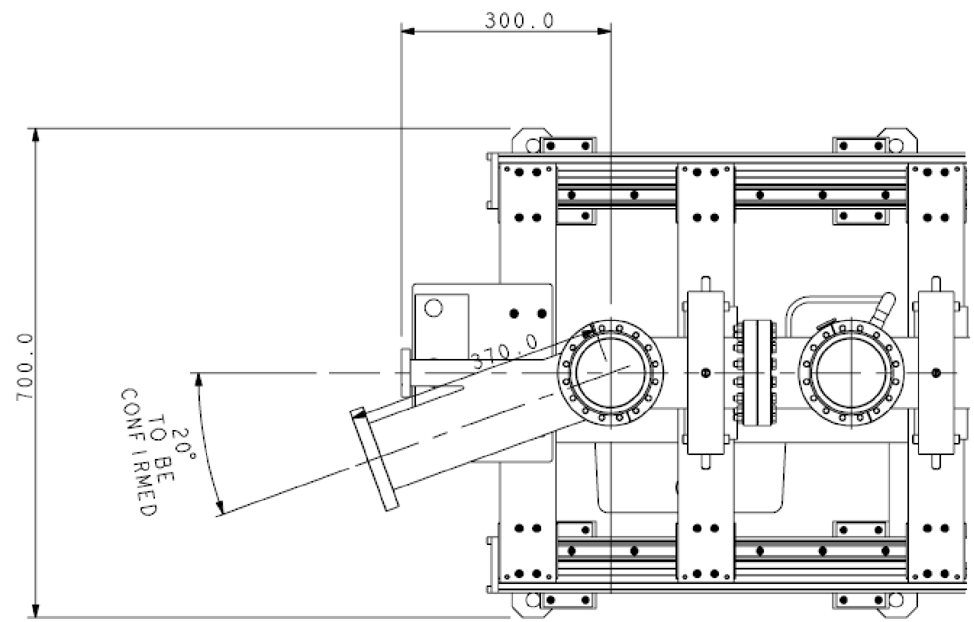


Simulations

The aim of simulations was two fold.

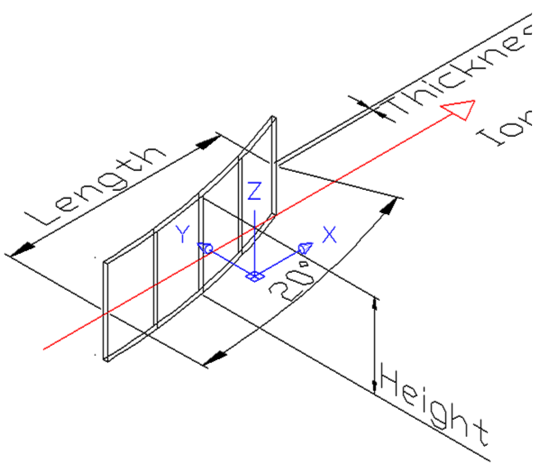
- optimize the shape and the size of deflection plates to be installed at the 34   and 20   bend.
- optimize transmission of the beam through the chamber to the detection system at the end station

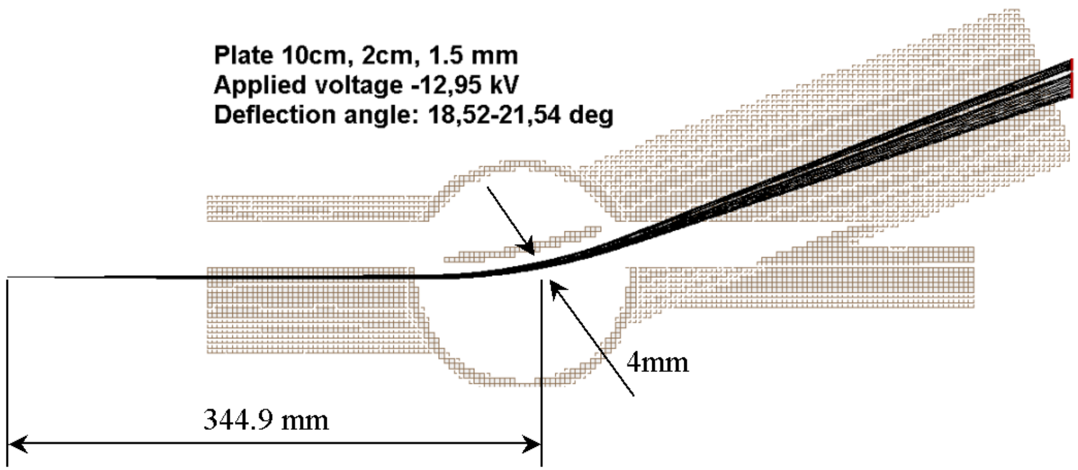




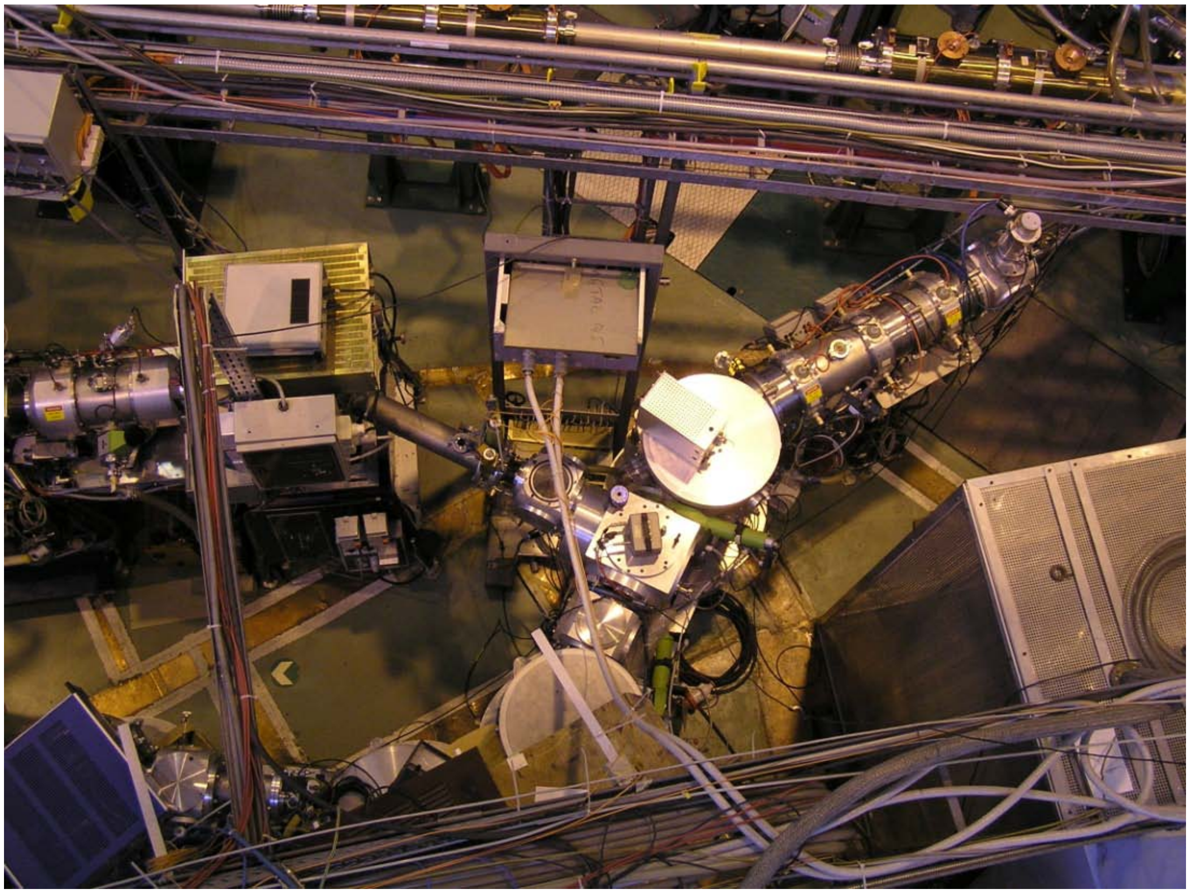
Simulations

- All simulations have been performed with the SIMION 8.
- A single curved plate design was realised for 20 bend ion deflector
- Two quadrupole doublets introduced in the beam line to optimize beam transport efficiency to the detector endstation





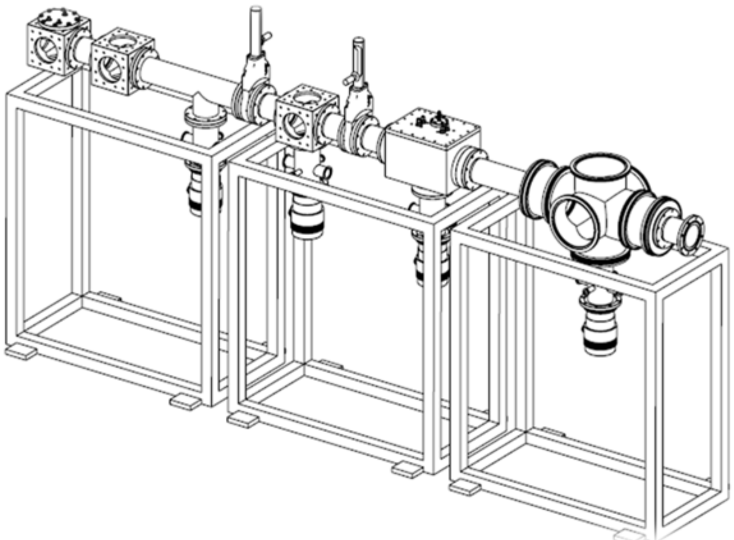
Status in Spring 2008



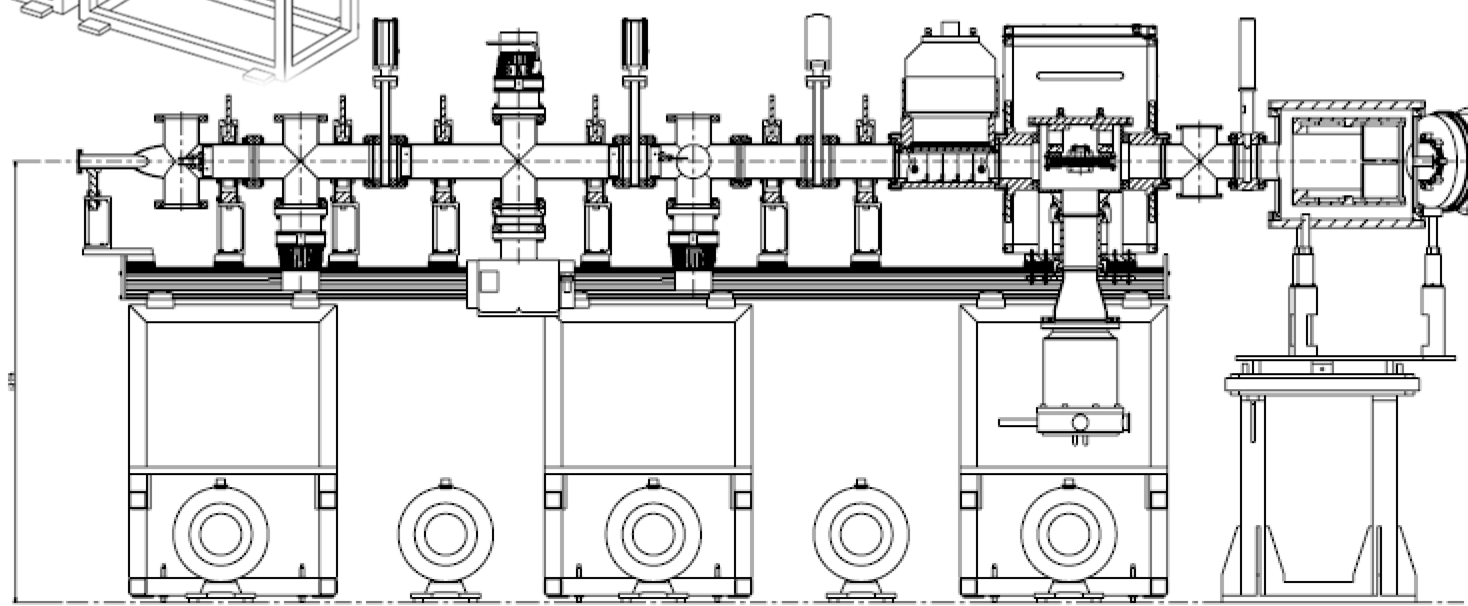
COMPLIS experiment beam line.

Quadrupole Triplet and 34 degree bend retained for CRIS

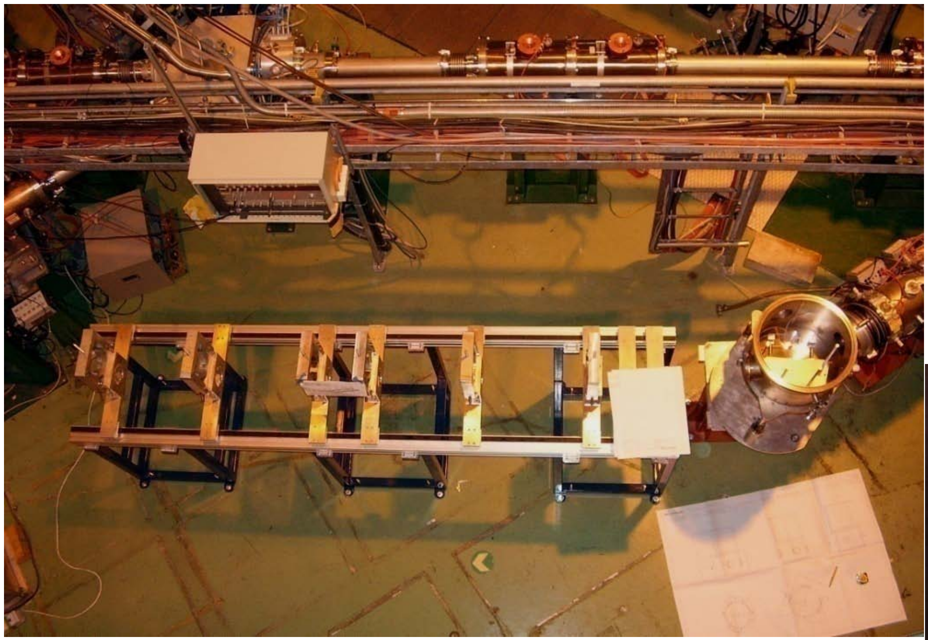
Evolution of design during 2008



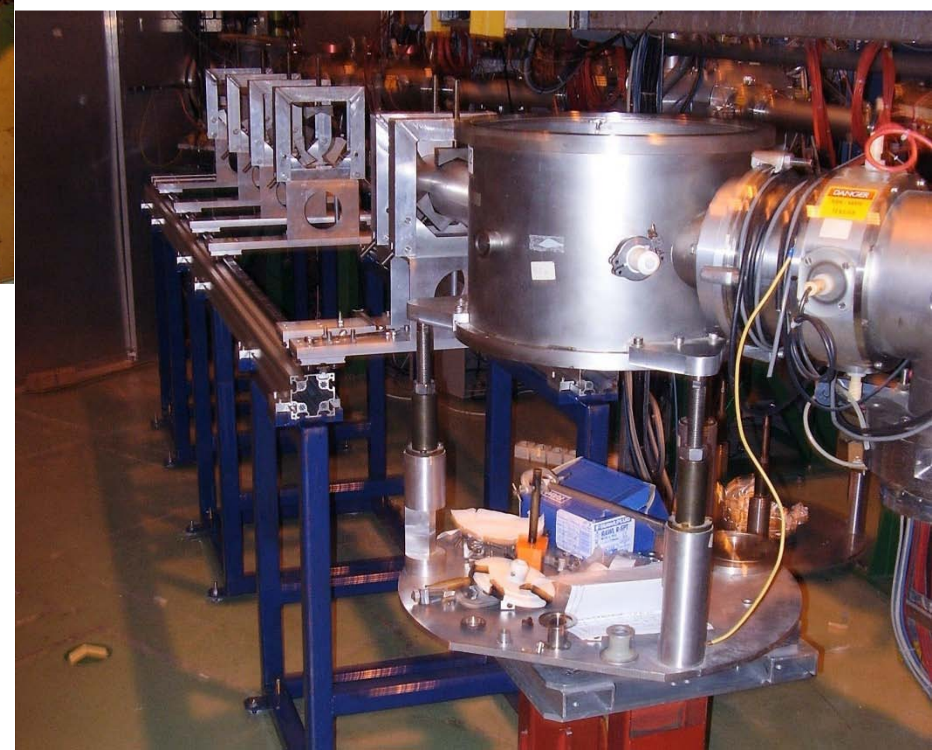
Basic scheme went through several iterations before converging on the final design.
UHV requirements constrained the design and forced the beam line to be ~3m in length



November 2008



"Railway track" installation

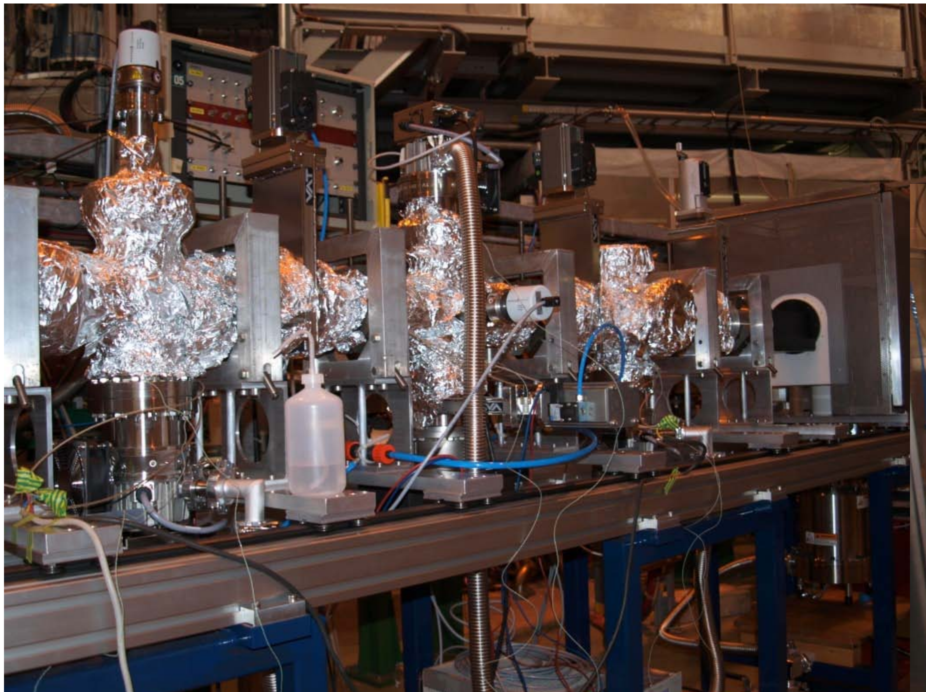


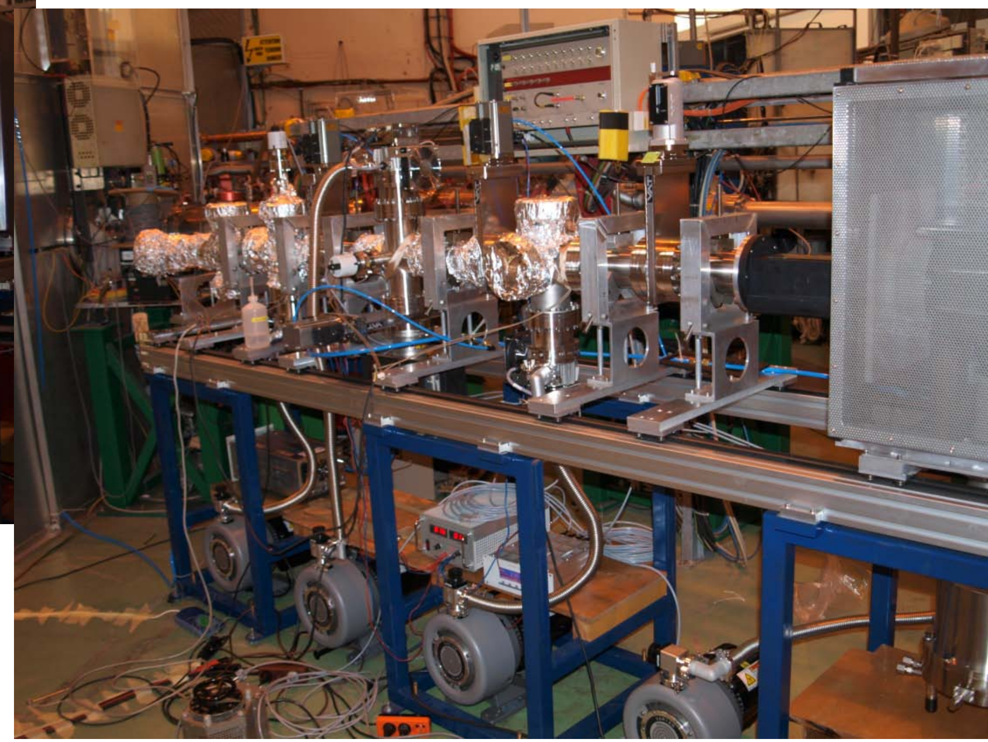
Allows one person to open the vacuum system and move chambers.

April 2009

Delivery of vacuum chambers, Faraday cage, charge exchange cell and installation of pumps.

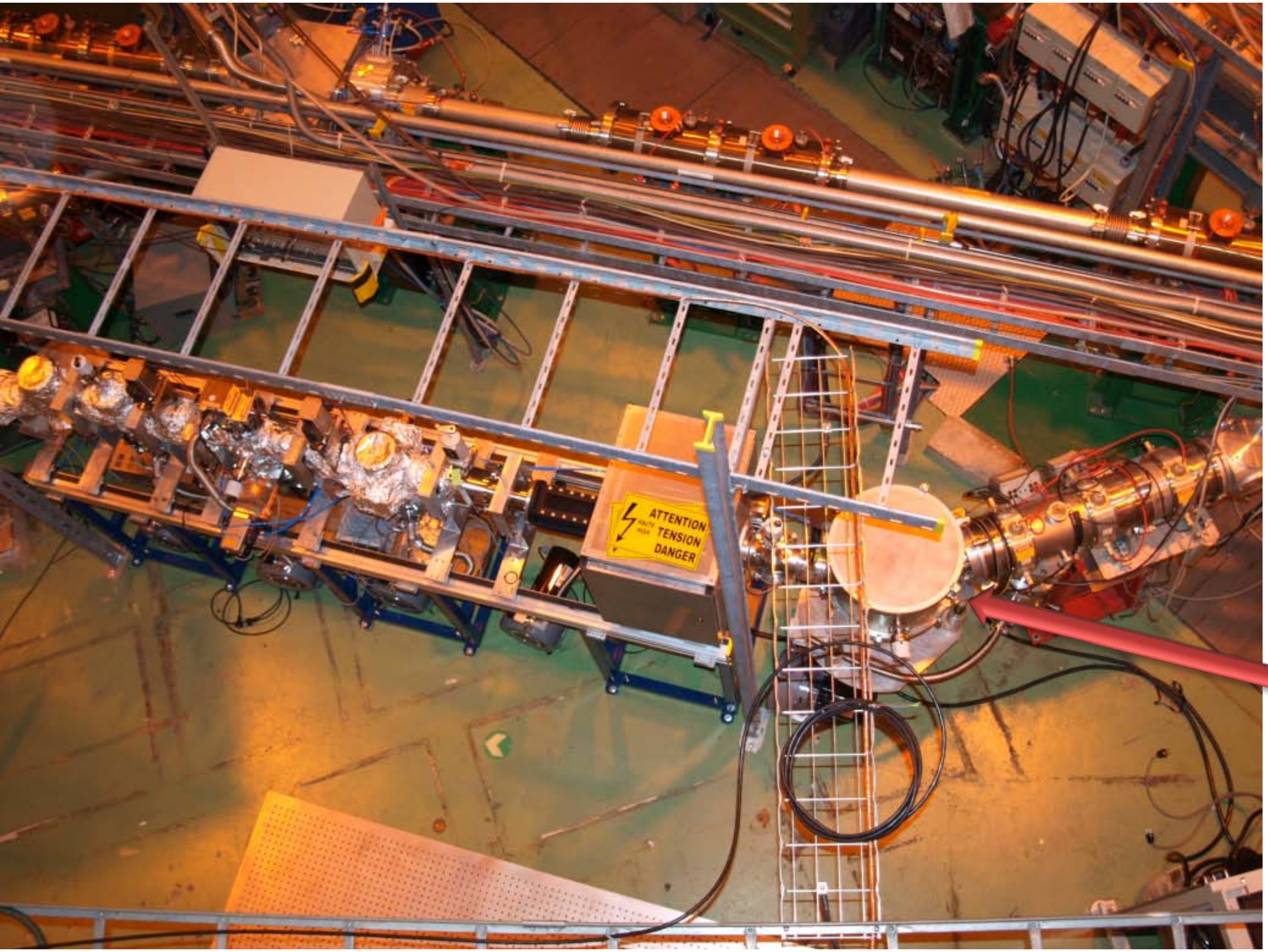
July 2009





Vacuum testing, initial bake-out of UHV section reached <5e-9mbar (limit of the gauge) in the interaction region.

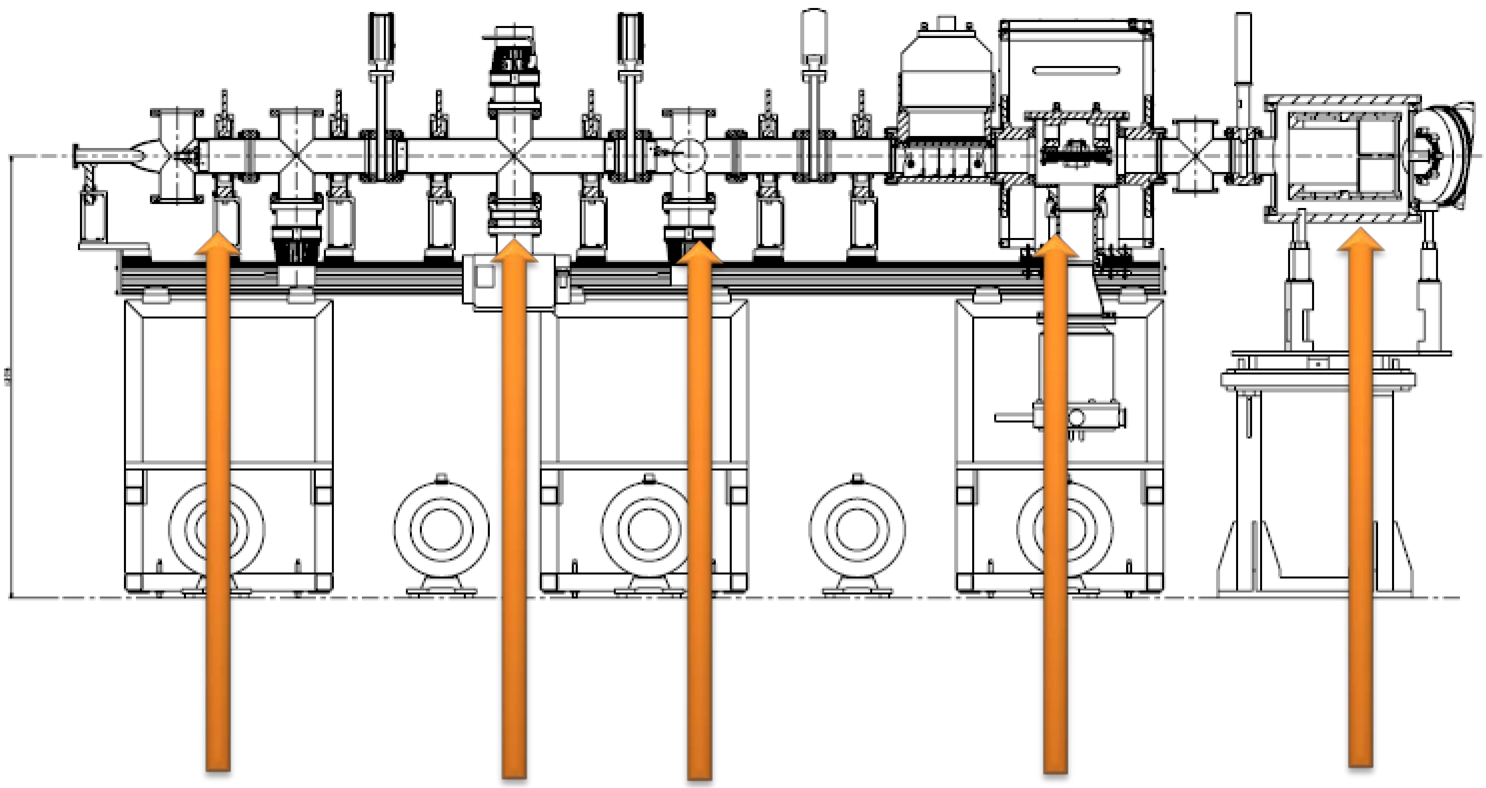
November 2009



ISOLDE beam from HRS

Laser launch direction into the beam line

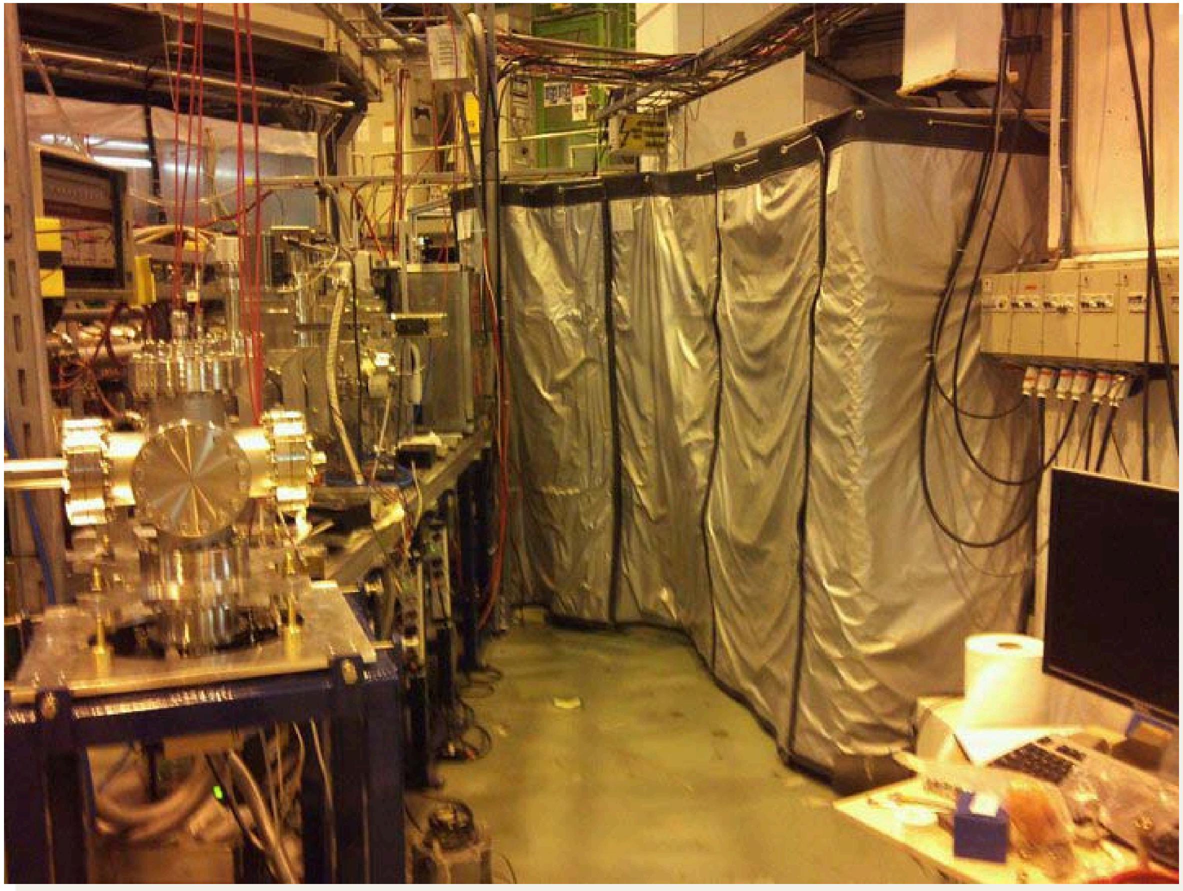
December 2009



9.11e-9 mbar <5e-9 mbar 7.24e-8mbar 9.64e-7mbar 7.5e-7mbar

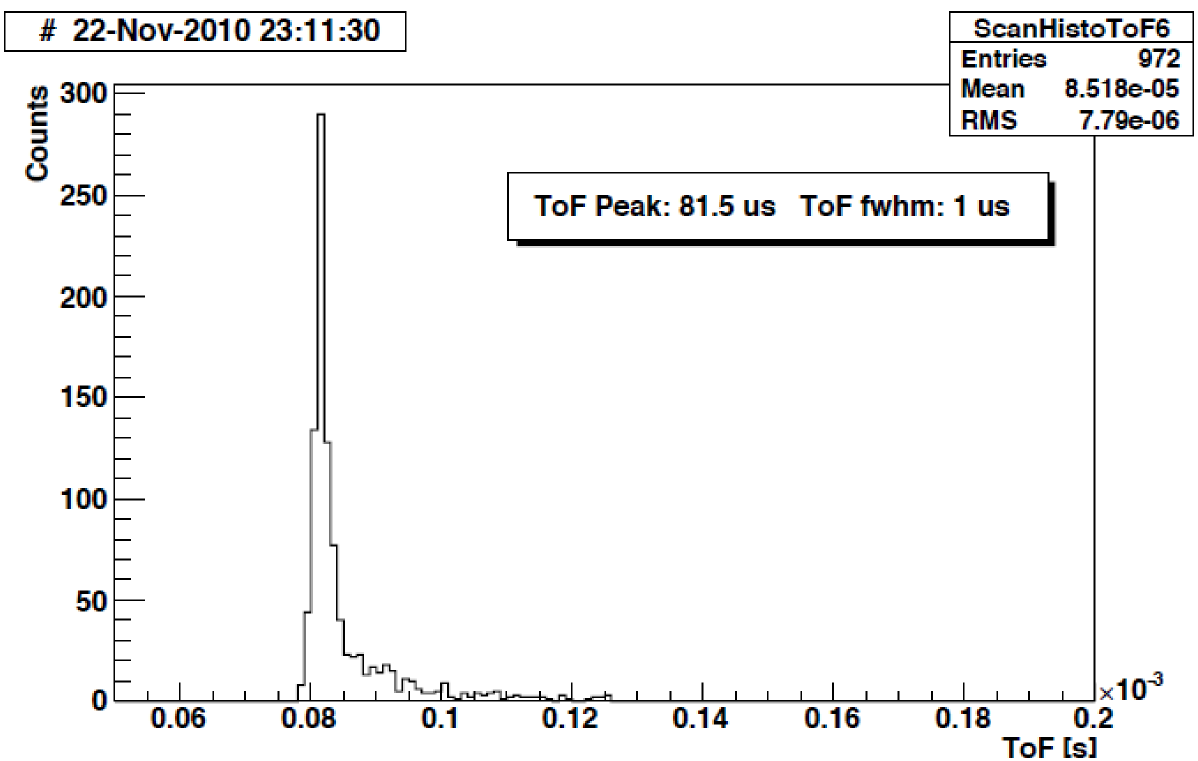
2010

- Installed
  - quadrupole doublet
  - Faraday cups
  - MCP detector
  - Laser optics

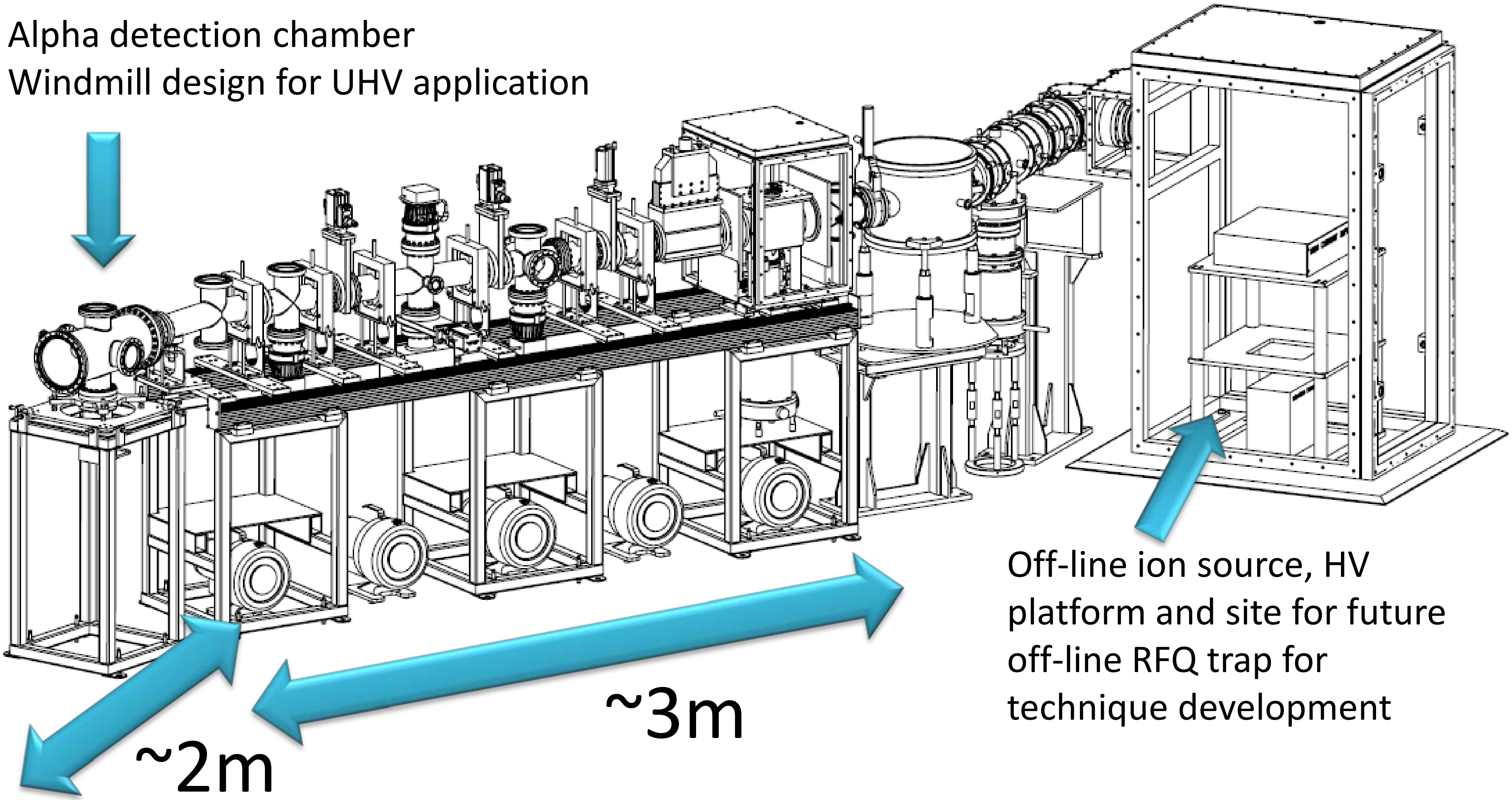


November tests

- Beam tuning (>70% to interaction region)
- Charge exchange (typically 75%)
- UHV (< 5 x 10^{-9} mbar)
- 1μs FWHM

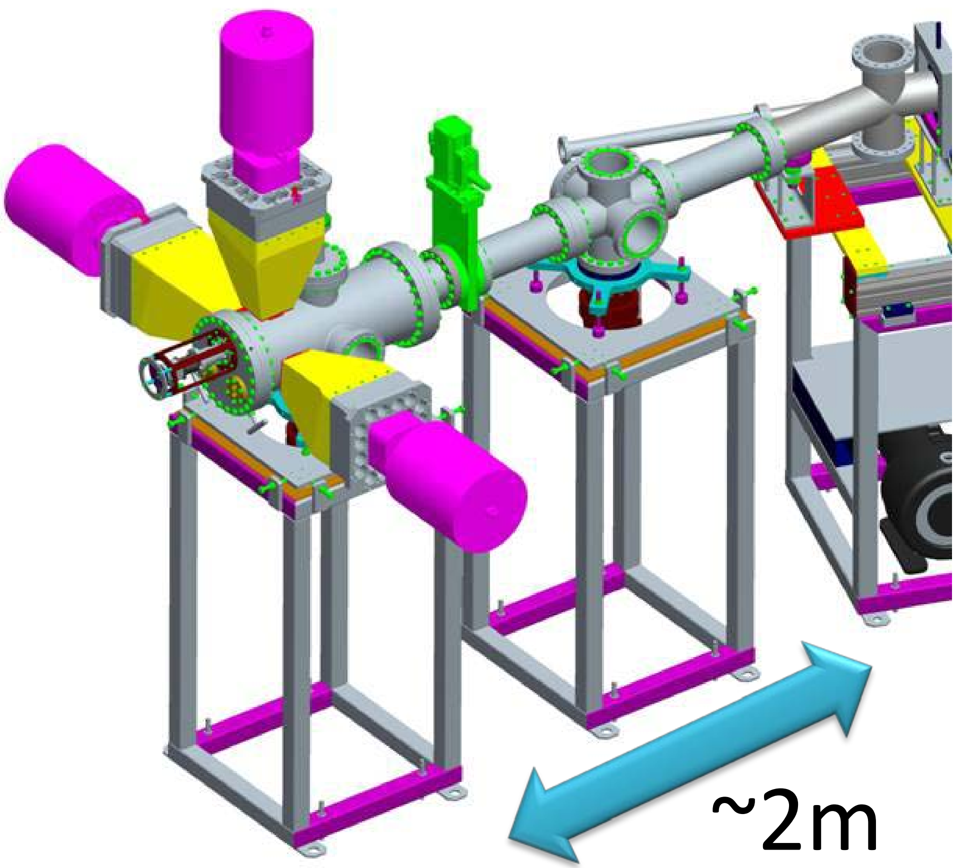


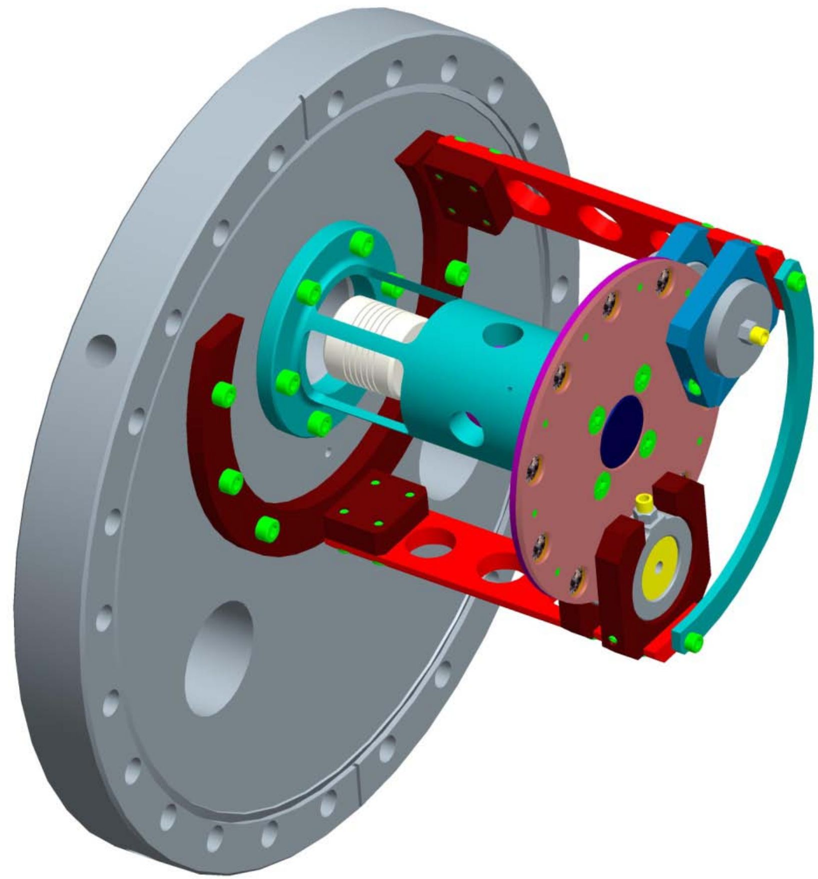
2010-2011

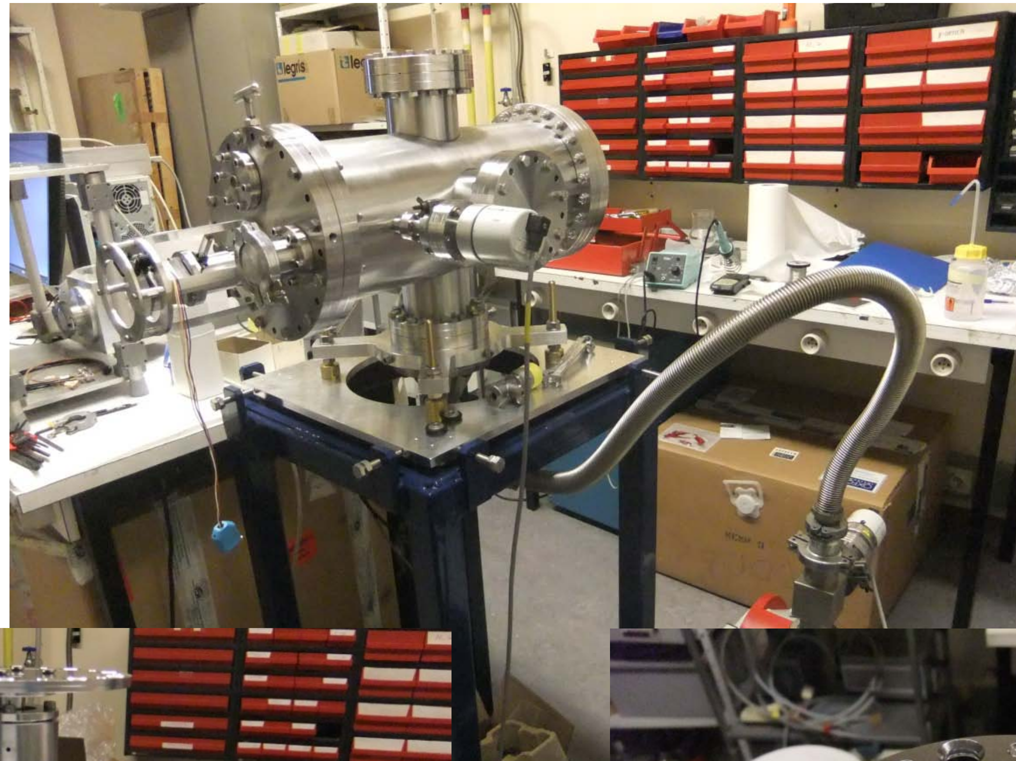

Alpha detection chamber
Windmill design for UHV application
Off-line ion source, HV platform and site for future off-line RFQ trap for technique development
~3m
~2m

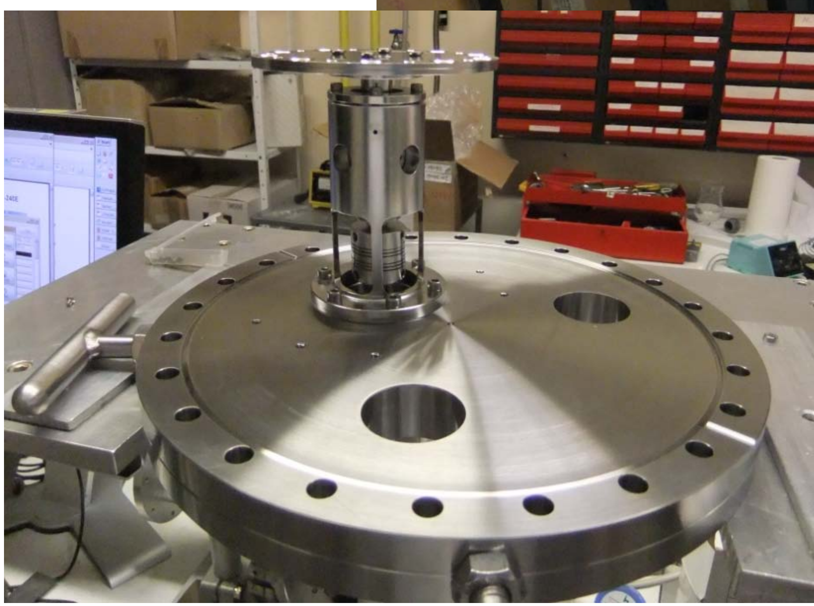
Laser Assisted Decay Spectroscopy:LADS

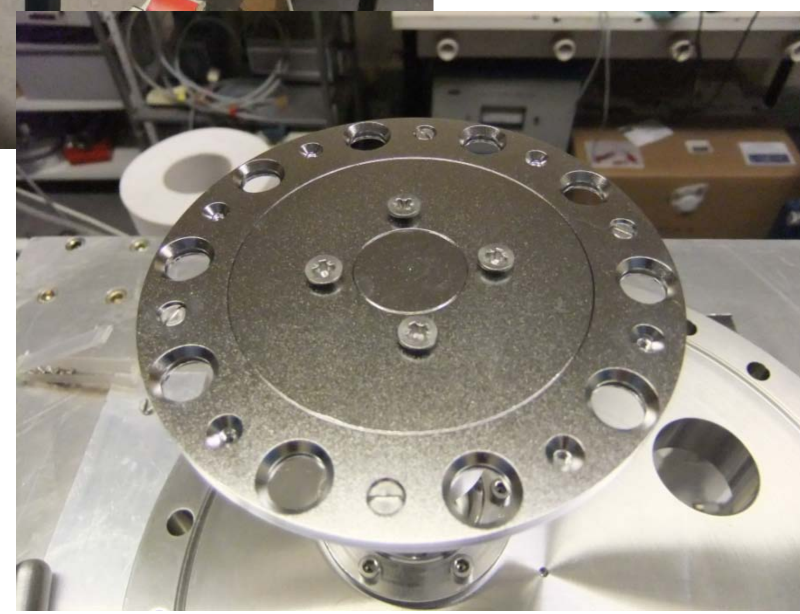
Possible option: 3 EUROGAM / EUROBALL detectors






legris



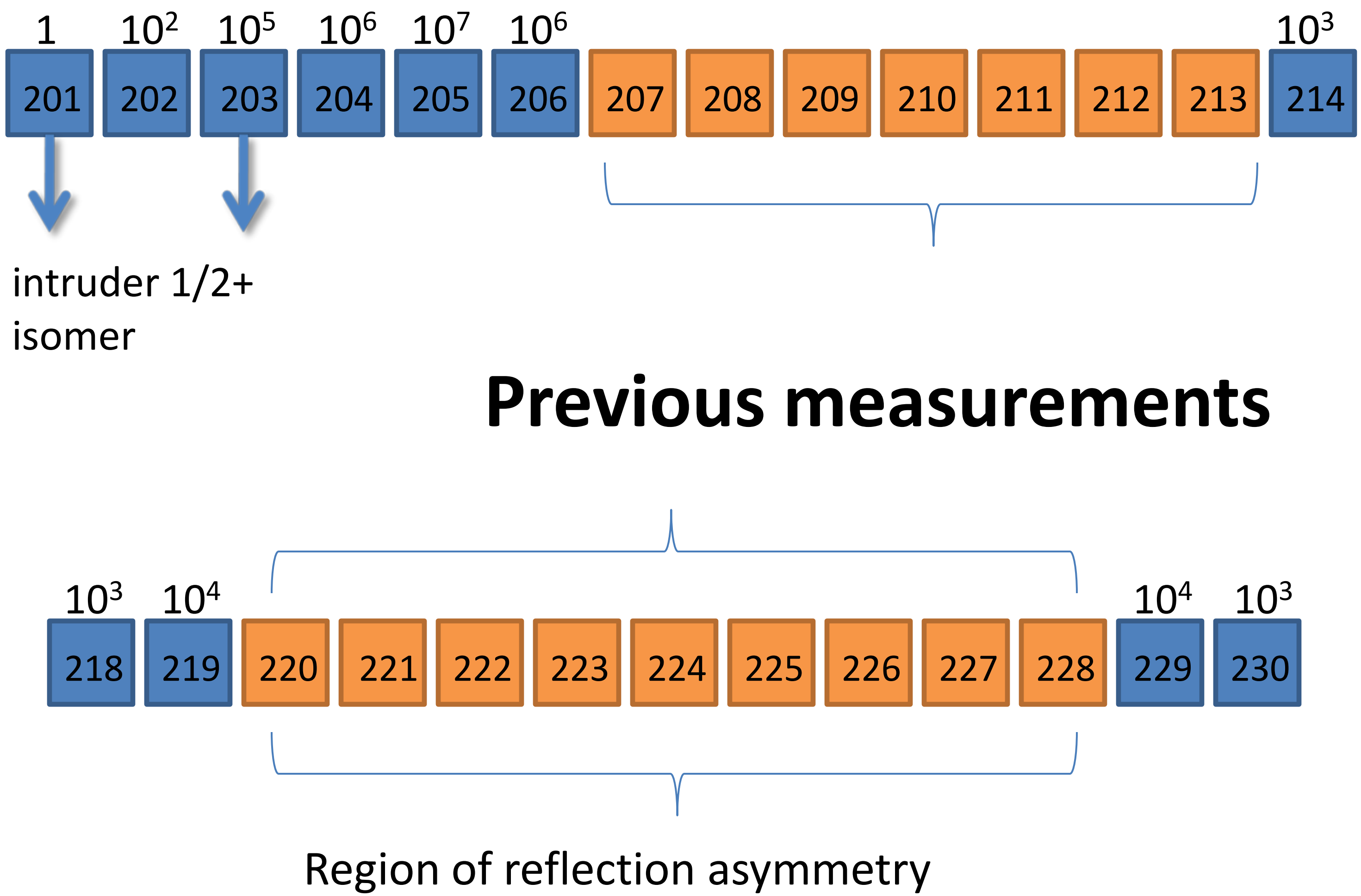


Thank you for your attention

Collaboration

J. Billowes, B. Cheal, T.E. Cocolios, K.T. Flanagan, D.H. Forest, R. Hayano, M. Hori, T. Kobayashi, F. Le Blanc, O. Levinkron, D. Lunney, K.M. Lynch, G. Neyens, T. Procter, M.M. Rajabali, S. Rothe, H.H Stroke, G. Tungate, W. Vanderheijden, P. Vingerhoets, K. Wendt.

Previous and proposed isotopes



2011:Novel Laser System for on-line radioactive beam research.

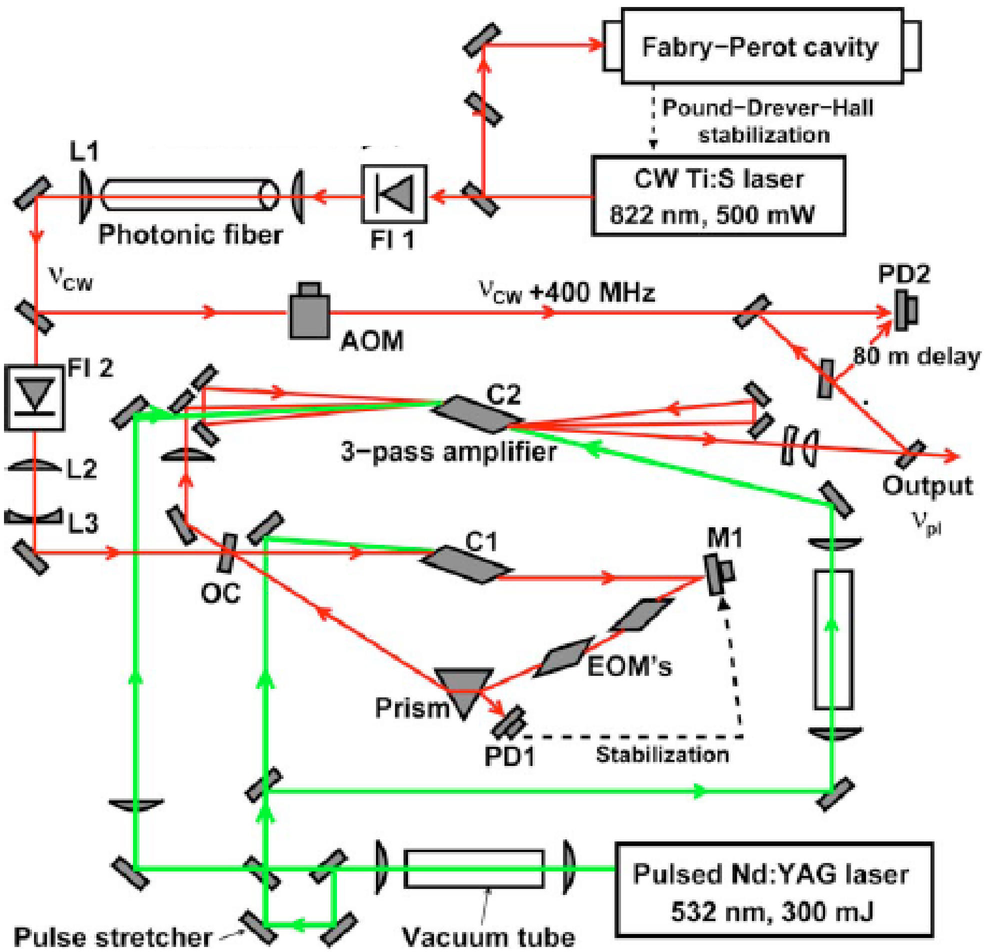
M. Hori and A. Dax

OPTICS LETTERS **34,** 1273 (2009)

Tested tuning range 726–941 nm

Line width ~6MHz

E=50–100 mJ



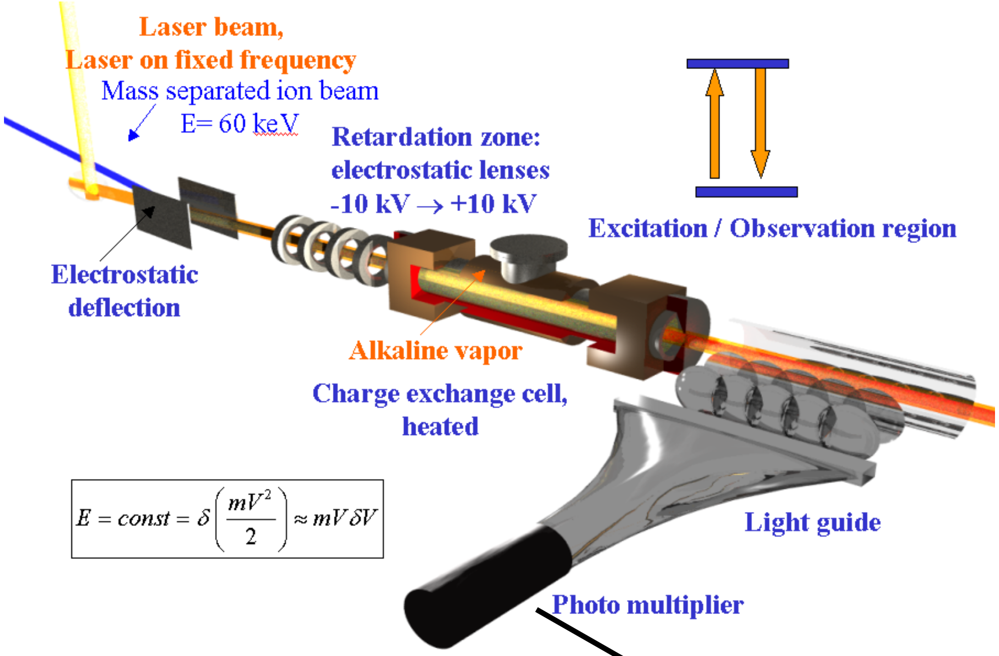
Replacing CW TiSa with a diode laser system (845nm, 300mW)

Turn key table top system with minimal interventions during operation.

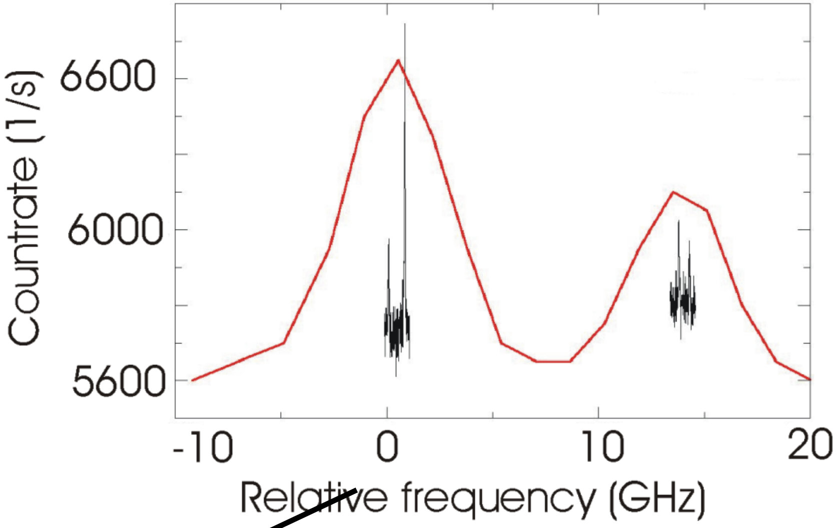
Novel laser system for radioactive ion beam facilities

The basic principle of CRIS technique

CS – Collinear laser spectroscopy

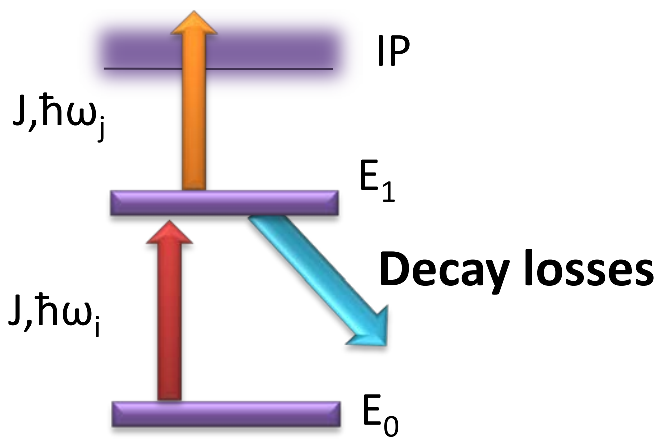


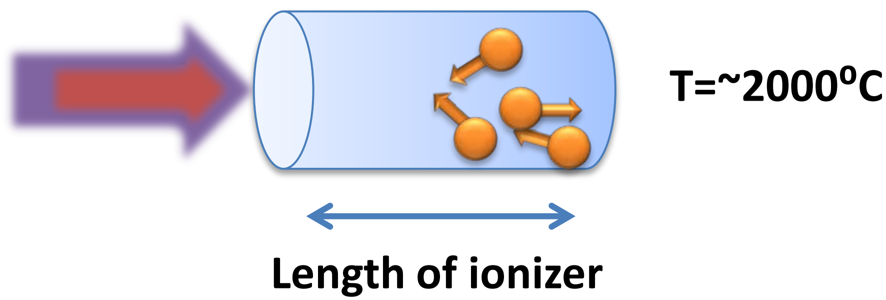
RIS- Resonant ionization spectroscopy



CRIS

Considerations for in-source laser spectroscopy





Evacuation time ~100µs
Therefore a repetition rate of 10kHz is required for maximum efficiency.

•Need to satisfy the Flux and Fluence conditions in order to saturate transitions and maximise efficiency.
•Short duration pulsed lasers (10-20ns) with ~1-10mJ per pulse.
•CW Laser> 500W (and tight focus) just to saturate the first step!

~100mW at 10kHz for resonant steps
~1-5W at 10kHz for quasi resonant steps
~10-20W at 10kHz for non-resonant steps